CLAIMS

What is claimed is:

1. An microreactor for synthesizing colloidal nanoparticles comprising:

at least one inlet channel;

at least one micromixing block positioned downstream from said at least one inlet channel;

an aging section positioned downstream from said at least one micromixing block channel; and

at least one outlet channel positioned downstream from said aging section.

2. The microreactor of claim 1, further comprising an ultrasonication means.

3. The microreactor of claim 2, wherein the ultrasonication means is an ultrasonication bath into which the microreactor or a portion thereof is emersed.

4. The microreactor of claim 2, wherein the ultrasonification means is an ultrasonification transducer that is attached to the microreactor.

5. The microreactor of claim 1 wherein the width of said at least one inlet channel is in the range of between about 10 μm and about 5000 μm.

6. The microreactor of claim 1 wherein the depth of said at least one inlet channel is in the range of between about 10 μm and about 2000 μm.

7. The microreactor of claim 1 wherein said aging section comprises at least one aging channel.

8. The microreactor of claim 7 wherein the length of said at least one aging channel is in the range of between about 1 mm and about 100 cm.

9. The microreactor of claim 7 wherein the width of said at least one aging channel is in the range of between about 10 μm and about 5000 μm.

10. The microreactor of claim 7 wherein the depth of said at least one aging channel is in the range of between about 10 μm and about 2000 μm.

11. The microreactor of claim 1 wherein a first reactant stream is introduced into said microreactor at a first inlet channel.

12. The microreactor of claim 11 wherein a second reactant stream is introduced into said microreactor at a second inlet channel.

13. The microreactor of claim 12 wherein a third reactant stream is introduced into said microreactor at a third inlet channel.

14. The microreactor of claim 1 wherein more than one reactant stream are introduced into said microreactor through one inlet channel.

15. The microreactor of claim 1 wherein said microreactor employs solution-based sol-gel processing.

16. The microreactor of claim 15 wherein a first reactant stream introduced into said microreactor comprises alkoxide in alcohol.

17. The microreactor of claim 16 wherein a second reactant stream introduced into said microreactor comprises water in alcohol.

18. The microreactor of claim 1 wherein said reactant streams have flow rates in the range of between about 0.1 μm/min. and about 10 mL/min.

19. The microreactor of claim 1 wherein said colloidal nanoparticles synthesized are Silica.

20. The microreactor of claim 19 wherein the silica nanoparticles are prepared from a tetraethyl-orthosilicate precursor.

21. The microreactor of claim 1 wherein said colloidal nanoparticles synthesized are Titania.

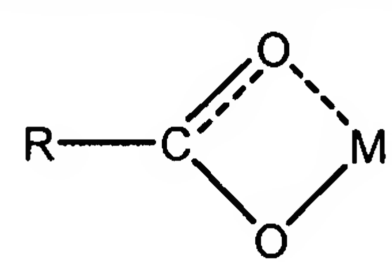
22. The microreactor of claim 21 wherein the titania nanoparticles are prepared from a titanium tetraethoxide precursor.

23. The microreactor of claim 21 wherein the titania nanoparticles are prepared from a titanium n-butoxide precursor.

24. The microreactor of claim 1, wherein the colloidal nanoparticles synthesized are alumina.

25. The microreactor of claim 1, wherein the colloidal nanoparticles synthesized are ceria.

26. The microreactor of claim 1, wherein the colloidal nanoparticles are prepared from one or more compounds represented by the following structural formula:



wherein:

M is La, Sr, Mn, Fe, Co, Ce, Gd, Cu, or Ni; and

R is an alkyl, aryl or arylalkyl group.

27. The microreactor of claim 1 wherein said colloidal nanoparticles have monodisperse size distributions.

28. The microreactor of claim 1 wherein said colloidal nanoparticles have polydisperse size distributions.

29. The microreactor of claim 1 wherein said colloidal nanoparticles have precisely defined polydisperse size distribution.

30. The microreactor of claim 1 wherein said colloidal nanoparticles are charged.

31. The microreactor of claim 1 wherein said micromixing block has one or more channels that have a width of between about 1 μm and about 200 μm.

32. The microreactor of claim 1 wherein said micromixing block has one or more channels that have a depth of between about 10 μm and about 2000 μm.

33. The microreactor of claim 1 further comprising a quench fluid inlet port downstream from said aging section and upstream from said at least one outlet channel.

34. The microreactor of claim 33 wherein said quench fluid is an inert solvent.

35. The microreactor of claim 33 wherein said quench fluid is alcohol.

36. The microreactor of claim 33 wherein said quench fluid is introduced into said microreactor at a flow rate equal to or greater than the flow rate of said reacting fluids.

37. The microreactor of claim 33 wherein the introduction of said quench fluid into the microreactor stops the colloidal nanoparticle growth.

38. An electrophoretic switch comprising:

a first inlet channel for introducing a first liquid stream into said electrophoretic switch, wherein the first liquid stream comprises suspended nanoparticles;

a second inlet channel separate from said first inlet channel for introducing a second liquid stream into said electrophorectic switch;

a switch channel downstream from said first and second inlet channels, wherein said first liquid stream and said second liquid stream are contacted at an interface;

at least one negatively charged electrode on one side of the interface;

at least one positively charged electrode on the opposite side of the interface from the at least one negatively charged electrode; and

at least one exit channel downstream from said switch channel.

39. The electrophoretic switch of claim 38, wherein the second liquid comprises a coating reactant.

40. The electrophoretic switch of Claim 38, wherein the second liquid is a purification solvent.

41. The electrophoretic switch of claim 38 wherein said nanoparticles are transferred in the switch channel from said first liquid stream to said second liquid stream by electrophoresis.

42. The electrophoretic switch of claim 38 wherein said nanoparticles are transferred in the switch channel from said first liquid stream to said second liquid stream by dielectrophoresis.

43. The electrophoretic switch of claim 38 wherein the width of said switch channel is in the range of between about 1 μm and about 5 mm.

44. The electrophoretic switch of claim 38 wherein the depth of said switch channel is in the range of between about 10 μm and about 2000 μm.

45. The electrophoretic switch of claim 38 wherein the length of said switch channel is in the range of between about 1 mm and about 1 m.

46. The electrophoretic switch of claim 38 wherein said contacted liquids are separated at said at least one exit channel.

47. The electrophoretic switch of claim 38 wherein said at least one exit channel further comprises:

a first exit channel for exiting liquid waste; and

a second exit channel separate from, and adjacent to, said first exit channel for exiting nanoparticles.

48. The electrophoretic switch of claim 38 wherein the reactant streams have a flow rate in the range of between about 1 μL/min and about 100 μL/min at said at least one exit channel.

49. The electrophoretic switch of claim 38 wherein said electrodes are made of a material selected from the group consisting of gold, platinum, copper, nickel, silver, palladium, indium-tin oxide, and combinations thereof.

50. The electrophoretic switch of claim 38 wherein a voltage applied across said electrodes is in the range of between about 0.1 V DC and about 120 V DC.

51. An apparatus for synthesizing colloidal nanoparticles, coating colloidial nanoparticles, or both synthesizing and coating colloidal nanoparticles comprising the following components:

at least one microreactor; and

at least one electrophoretic switch, wherein each component is connected to at least one other component.

52. The apparatus of claim 51, wherein each component is a separate module.

53. The apparatus of claim 51, wherein all components are on the same module.

54. The apparatus of claim 51, wherein all of the components are connected in series.

55. The apparatus of claim 51, further comprising an ultrasonication means.

56. The apparatus of claim 55, wherein the ultrasonication means is an ultrasonication bath into which the microreactor or a portion thereof is emersed.

57. The apparatus of claim 55, wherein the ultrasonification means is an ultrasonification transducer that is attached to the microreactor.

58. The apparatus of claim 51 wherein said microreactor comprises:

at least one micromixing block positioned downstream from at least one inlet channel;

an aging section positioned downstream from said at least one micromixing block channel; and

at least one outlet channel positioned downstream from said aging section.

59. The apparatus of claim 58 wherein the width of said at least one inlet channel is in the range of between about 10 μm – 5000 μm.

60. The apparatus of claim 58 wherein the depth of said at least one inlet channel is in the range of between about 10 μm to about 2000 μm.

61. The apparatus of claim 58 wherein said aging section comprises at least one aging channel.

62. The apparatus of claim 61 wherein the length of said at least one aging channel is in the range of between about 1 mm and about 100 cm.

63. The apparatus of claim 61 wherein the width of said at least one aging channel is in the range of between about 10 μm and about 5000 μm.

64. The apparatus of claim 61 wherein the depth of said at least one aging channel is in the range of between about 10 μm and about 2000 μm.

65. The apparatus of claim 58 wherein a first reactant stream is introduced into said microreactor at a first inlet channel.

66. The apparatus of claim 65 wherein a second reactant stream is introduced into said microreactor at a second inlet channel.

67. The apparatus of claim 66 wherein a third reactant stream is introduced into said microreactor at a third inlet channel.

68. The apparatus of claim 58 wherein more than one reactant stream are introduced into said microreactor through one inlet channel.

69. The apparatus of claim 66 wherein a first reactant stream introduced into the microreactor comprises alkoxide in alcohol.

70. The apparatus of claim 69 wherein a second reactant stream introduced into the microreactor comprises water in alcohol.

71. The apparatus of claim 51 wherein said reactant streams have flow rates in the range of between about 0.1 μL/min. to about 10 μl/min.

72. The apparatus of claim 51 wherein said microreactor employs solution-based sol-gel processing.

73. The apparatus of claim 72 wherein said colloidal nanoparticles synthesized are Silica.

74. The apparatus of claim 73 wherein the silica nanoparticles are prepared from a tetraethyl-orthosilicate precursor.

75. The apparatus of claim 51 wherein said colloidal nanoparticles synthesized are Titania.

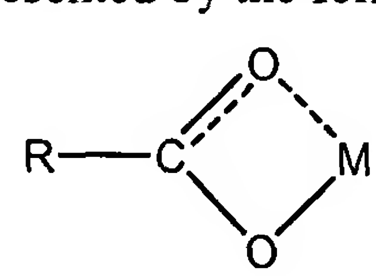
76. The apparatus of claim 75 wherein the titania nanoparticles are prepared from a titanium tetraethoxide precursor.

77. The apparatus of claim 75 wherein the titania nanoparticles are prepared from a titanium n-butoxide precursor.

78. The apparatus of claim 72, wherein the colloidal nanoparticles synthesized are alumina.

79. The apparatus of claim 72, wherein the colloidal nanoparticles synthesized are ceria.

80. The apparatus of claim 72, wherein the colloidal nanoparticles are prepared from one or more compounds represented by the following structural formula:



wherein:

M is La, Sr, Mn, Fe, Co, Ce, Gd, Cu, or Ni; and

R is an alkyl, aryl or arylalkyl group.

81. The apparatus of claim 51 wherein said colloidal nanoparticles prepared have monodisperse size distributions.

82. The apparatus of claim 51 wherein said colloidal nanoparticles have polydisperse size distributions.

83. The apparatus of claim 51 wherein said colloidal nanoparticles have precisely defined polydisperse size distribution.

84. The apparatus of claim 51 wherein said colloidal nanoparticles are charged.

85. The apparatus of claim 58 further comprising a quench fluid inlet port downstream from said aging section and upstream from said at least one outlet channel.

86. The apparatus of claim 85 wherein said quench fluid is an inert solvent.

87. The apparatus of claim 85 wherein said quench fluid is alcohol.

88. The apparatus of claim 85 wherein said quench fluid is introduced into said microreactor at a flow rate equal to or greater than the flow rate of said reacting fluids.

89. The apparatus of claim 51, wherein said at least one electrophoretic switch comprises:

a first inlet channel for introducing a first liquid stream into said electrophoretic switch, wherein the first liquid stream comprises suspended nanoparticles;

a second inlet channel separate from said first inlet channel for introducing a second liquid stream into said electrophorectic switch;

a switch channel downstream from said first and second inlet channels, wherein said first liquid stream and said second liquid stream are contacted at an interface;

at least one negatively charged electrode on one side of the interface;

at least one positively charged electrode on the opposite side of the interface from the at least one negatively charged electrode; and

at least one exit channel downstream from said switch channel.

90. The apparatus of claim 89, wherein the second liquid comprises a coating reactant.

91. The apparatus of claim 89, wherein the second liquid is a purification solvent.

92. The apparatus of claim 89 wherein said nanoparticles are transferred in the switch channel from said first liquid stream to said second liquid stream by electrophoresis.

93. The apparatus of claim 89 wherein said nanoparticles are transferred in the switch channel from said first liquid stream to said second liquid stream by dielectrophoresis.

94. The apparatus of claim 89 wherein the width of said switch channel is in the range of between about 1 μm and about 5 mm.

95. The apparatus of claim 89 wherein the depth of said switch channel is in the range of between about 10 μm and about 2000 μm.

96. The apparatus of claim 89 wherein the length of said switch channel is in the range of between about 1 mm and about 1 m.

97. The apparatus of claim 89 wherein said contacted liquids are separated at said at least one exit channel.

98. The apparatus of claim 89 wherein said at least one exit channel further comprises:

a first exit channel for exiting liquid waste; and

a second exit channel separate from, and adjacent to, said first exit channel for exiting nanoparticles.

99. The apparatus of claim 89 wherein the reactant streams have a flow rate in the range of between about 1 μL/min and about 100 μL/min at said at least one exit channel.

100. The apparatus of claim 89 wherein said electrodes are made of a material selected from the group consisting of gold, platinum, copper, nickel, silver, palladium, indium-tin oxide, and combinations thereof.

101. The apparatus of claim 89 wherein a voltage applied across said electrodes is in the range of between about 0.1 V DC and about 120 V DC.

102. The apparatus of Claim 89, comprising:

one microreactor, comprising an aging channel; and

two electrophoretic switches, wherein the first electrophoretic switch is upstream from the microreactor and the second electrophoretic switch is down stream from the microreactor.

103. The apparatus of claim 102, wherein the second liquid of the first electrophoretic switch comprises a coating reactant.

104. The apparatus of claim 103 wherein said contacted liquids of the first electrophoretic switch are separated at said at least one exit channel.

105. The apparatus of claim 104 wherein said at least one exit channel of the first electrophoretic switch further comprises:

a first exit channel for exiting liquid waste; and

a second exit channel connected to the microreactor, separate from, and adjacent to, said first exit channel for exiting nanoparticles.

106. The apparatus of claim 105, wherein the second liquid of the second electrophoretic switch comprises a purification solvent.

107. The apparatus of claim 106 wherein said contacted liquids of the second electrophoretic switch are separated at said at least one exit channel.

108. The apparatus of claim 107 wherein said at least one exit channel of the second electrophoretic switch further comprises:

a first exit channel for exiting liquid waste; and

a second exit channel, separate from, and adjacent to, said first exit channel for exiting nanoparticles.

109. A method of synthesizing and coating colloidal nanoparticles comprising:

introducing reactants for forming said nanoparticles into a microreactor, thereby forming synthesized colloidal nanoparticles in a reaction mixture; and

introducing said reaction mixture into an electrophoretic switch downstream from said microreactor, wherein the electrophoretic switch extracts said nanoparticles from said reaction mixture into a coating liquid, thereby coating said nanoparticles.

110. The method of claim 109, wherein the reactants for forming nanoparticles comprise tetraethyl-silcate and the nanoparticles synthesized are silica nanoparticles.

111. The method of claim 109, wherein the coating liquid comprises an oligonucleotide, peptide or protein and the nanoparticles are coated with said ooigonucleotide, peptide or protein.

112. The method of claim 109, further comprising the steps of:

introducing the coating liquid into an aging channel downstream from said electrophoretic switch; and

introducing said coating liquid into a second electrophoretic switch downstream from said aging channel, wherein the electrophoretic switch extracts the coated nanoparticle into a purification solvent.

113. A method of coating colloidal nanoparticles comprising:

introducing a mixture containing nanoparticles into an electrophoretic switch, wherein the electrophoretic switch extracts said nanoparticles from said mixture into a coating liquid, thereby coating said nanoparticles.

114. The method of claim 113, wherein the coating liquid comprises an oligonucleotide, peptide or protein and the nanoparticles are coated with said ooigonucleotide, peptide or protein.

115. The method of claim 113, further comprising the steps of:

introducing the coating liquid into an aging channel downstream from said electrophoretic switch; and

introducing said coating liquid into a second electrophoretic switch downstream from said aging channel, wherein the electrophoretic switch extracts the coated nanoparticles from said coating liquid into a purification solvent.